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ERROR IN AIRSPEED MEASUREMENT DUE TO STATIC PRESSURE

FIELD AHEAD OF SHARP-NOSE BODIES OF

REVOLUTION AT TRANSONIC SPEEDS

By Edward C. B. Danforth and J. Ford Johnston

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RESEARCH MEMORANDUM

ERROR IN AIRSPEED MEASUREMENT DUE TO STATIC-PRESSURE
FIELD AHEAD OF SHARP-NOSE BODIES OF
REVOLUTION AT TRANSONIC SPEEDS

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SUMMARY

As part of a study of means of airspeed measurement at transonic speed, studies have been made at Mach numbers up to 1.1 by the NACA wing-flow method of the static-pressure (or position) error ahead of two sharp-nose bodies of revolution at zero angle of attack.

A method is shown by which the linearized subsonic theory and the transonic similarity rule can be applied to the data contained herein to predict the position error at any reasonable distance ahead of any sharp-nose body of revolution with an approximately parabolic nose profile and fineness ratio greater than about 4.5.

It was found that, by locating the static orifices a sufficient distance ahead of the nose of a body, the position error can be made small at low Mach numbers and will increase only slightly with Mach number until it disappears abruptly after passage of the bow shock wave. The low-speed and peak position errors both increased as the orifices were moved toward the body nose.

In the range of applicability of the linearized subsonic theory, that is, at Mach numbers below that for the first appearance of sonic speed on the body, the prediction of the linearized theory that the position error is independent of Mach number was experimentally verified. The magnitude of the position error in this Mach number range was also adequately predicted by the theory.

For slender bodies of a given thickness distribution in the range of Mach number for which the position error is constant, the position error at a given fraction of the body length ahead of the nose was found experimentally to be inversely proportional to the square of the fineness ratio.

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The transonic similarity rule for axially symmetric flow was found to furnish a good correlation of the position errors of the two bodies at all Mach numbers greater than about 0.9.

The static-pressure rise through the bow shock wave was found in all cases to be about 4 percent of stream impact pressure greater than that indicated by the normal shock theory. More startling was the appearance of a shock involving a pressure rise of 4 percent of stream impact pressure at a Mach number of 1.0 where the theory indicates that no finite shock should exist. Inasmuch as no evidence was found to indicate an error of this magnitude in the experimental data, it would appear that this phenomenon warrants further investigation.

INTRODUCTION

The precision with which airspeed and altitude can be measured in flight by a pitot-static tube depends upon the accuracy with which the free-stream total and static pressures are determined. The error introduced inherently by a well-designed pitot-static airspeed head, as exemplified by present high-speed types, is usually negligible both at subsonic and at supersonic speeds (references 1 and 2). The problem is then resolved into the choice of a location for the airspeed head at which the total and static pressures are affected only slightly by the pressure field of the airplane.

At subsonic speeds, there is no difficulty in the measurement of total pressure if the airspeed head is located well outside the propeller slipstream, the boundary layer, and the wake from the airplane structure. The static-pressure (or position) error can be minimized by locating the static orifices of the airspeed head sufficiently far ahead of the wing tip of the airplane (usually one chord length for research purposes). Satisfactory measurements of static pressure may also be obtained in some instances by fuselage static vents. The choice of a suitable vent location, however, must usually be made by trial in wind-tunnel or flight tests. It should be noted that the term "position error" as used in this paper refers only to the error due to the presence of the airspeed head in the pressure field of the body, although in flight test work position error is often used to include the airspeed-head error as well.

In the case of transonic or supersonic airplanes, the position error at the wing-tip position can be large and can vary considerably with Mach number because of the lateral expansion of the fuselage

pressure field at high Mach numbers. In addition, the position error at the wing tip will vary considerably with yaw at high Mach numbers, especially if the airspeed head is operating close behind the bow wave of the fuselage.

In general, the use of fuselage static vents will prove unsatisfactory at transonic speeds because of the large variation of the fuselage pressure distribution in this Mach number range. In special cases, however, fuselage vents may prove satisfactory at transonic speeds, for example, if located in the cylindrical portion of a fuselage of high-fineness ratio and sufficiently isolated from the pressure fields of the wing and tail.

The development of jet and rocket engines for aircraft has permitted the design of relatively sharp-nose fuselages. It has been suggested that an airspeed head located ahead of a sharp-nose fuselage may furnish a measurement of static pressure subject to only a small error throughout the entire range of Mach number.

The position error ahead of fuselage-like bodies at low subsonic speeds is reported in reference 3. It was shown that, at low Mach numbers, position errors of the order of $1\frac{1}{2}$ percent of stream impact pressure can be obtained at one diameter ahead of a sharp-nose body.

At supersonic speeds, it is evident that the position error will be zero at all points ahead of the body bow wave. Since for all supersonic Mach numbers, except those very near 1.0, the bow wave will lie close to the body nose, zero position error can be obtained with relatively short boom lengths.

Thus, while the position error ahead of a fuselage nose was known to be small at subsonic and supersonic speeds, no information, either experimental or theoretical, was available for predicting the magnitude of the error at transonic speeds. For this reason, the investigation of reference 3 was extended to transonic speeds by means of the NACA wing-flow method. The present investigation consisted of the measurement of the pressures at several distances ahead of two sharp-nose bodies of revolution at zero angle of attack between Mach numbers of 0.7 and 1.1. The results of the analysis of these measurements are reported herein. No measurements were made in this investigation of the loss in total pressure through shock ahead of the bodies. However, this loss is negligible at low supersonic speeds and may be calculated from the normal shock relations at higher Mach numbers, inasmuch as the pitot head is exposed to only a single shock whether caused by the fuselage or the head itself.

SYMBOLS

D	maximum body diameter
f, F, G	"function of"
K	a constant
$l/2$	distance from body nose to position of maximum diameter
M	Mach number
p	static pressure
Δp	differential pressure above static pressure of free stream
q	dynamic pressure
q_c	impact pressure
x	axial distance from nose of body
γ	ratio of specific heat at constant pressure to that at constant volume

MODELS

The general details of the two sharp-nose bodies of revolution used in this investigation may be seen by the photographs in figure 1 and the sketches in figure 2. Body A was of circular-arc profile and fineness ratio 6. Body B had a larger nose angle than body A, and its maximum thickness was forward of midlength. The shape of body B forward of maximum thickness was similar to that of the X-1 airplane without the cockpit and nose-gear enclosures. Each body was equipped with a cone-pointed static pressure tube of 0.060-inch diameter extending forward axially from the nose. This tube carried eight 0.010-inch-diameter orifices located 0.30 inch (five diameters) behind the shoulder of the cone point (short-nose static tube). Additional tests were carried out on body B with a similar tube having orifices located 1.20 inches (20 diameters) behind the shoulder (long-nose static tube).

METHOD AND TESTS

The static pressure at the model orifice position without the model in place was calibrated with respect to the static pressure at

two locations sufficiently forward and to the side of the model that they would be essentially unaffected by the model. The locations, one a static tube at the height of the model and one an orifice on the wing surface, are shown in figures 3 and 4. The calibrations are given in figure 5. The static-pressure error due to body A or B was taken as the difference between the relative pressures at the reference and test positions with and without the model in place. The calibration with respect to the static pressure tube (fig. 5(b)) has been used exclusively in the reduction of the data since it is less sensitive to changes in Mach number and consequently produced less scatter than the calibration with respect to the flush orifice (fig. 5(a)). The subscripts 1, 2, 3 in the coordinates of figure 5 refer to the points of static-pressure measurement shown in the sketch at the top of this figure.

The models were sting mounted, as shown by the example of body B in figure 6, at $6\frac{1}{4}$ inches above the airplane wing surface and were aligned with the local flow.

The tests were conducted in dives from high altitude during which the Mach number at the model position varied from about 0.7 to 1.1. The differential pressures between the model orifice position and the two reference positions were measured by sensitive differential-pressure recorders. Other standard NACA instruments recorded the absolute pressure at the reference static pressure tube and the airplane impact pressure.

Measurements of the position error have been made at distances of 0.6 and 1.5 body diameters ahead of body A and at 0.5, 0.75, and 1.7 body diameters ahead of body B. The position error of body A was obtained with the short-nose static pressure tube only, while that of body B was obtained with both the short and the long-nose tubes.

RESULTS AND DISCUSSION

Variation of Position Error with Mach Number

The results of the position-error measurements for body A are shown in figure 7 at distances ahead of the nose x/D (see fig. 2) of 0.6 and 1.5 and for body B in figure 8 at distances of 0.5D, 0.75D, and 1.7D. The position error $\Delta p/q_c$ is presented as the error in static pressure expressed as a fraction of the true impact pressure q_c at the model orifice position and is shown as a function of the Mach number at that point.

Variation below body critical Mach number.- It can be seen in figures 7 and 8 that the position error is essentially constant at

Mach numbers lower than about 0.9. This effect is predicted by the subsonic linearized theory (reference 4) which shows that the position error on the axis of a body of revolution, either ahead of or behind the body, is independent of Mach number to the first order. The position errors ahead of the two bodies have been calculated by the subsonic linearized theory and are represented in figures 7 and 8 by the triangular symbols. The agreement of the theoretical and measured position errors is generally very satisfactory. It would appear, therefore, that the bodies are sufficiently slender so that they do not grossly violate the thin-body assumption of the linearized theory.

It should be noted that throughout this paper the experimental values of position error expressed as a fraction of q_c are compared with theoretical values expressed as a fraction of q . This slight difference in the basis of comparison is of no consequence, since the linearized theory, which admits of no appreciable density variation, does not distinguish between q_c and q .

Variation above body critical Mach number.- Even for very slender bodies, the assumptions of the subsonic linearized theory become invalid if sonic speed is approached at some point on the body, and measurements are then expected to depart from the predictions of the theory. It is shown in reference 5 that sonic speed is first reached at the maximum thickness position of body A at a Mach number of about 0.92. The results of the present tests (fig. 7) show that, above a Mach number of about 0.9, the position error of body A is no longer constant but increases rapidly with Mach number.

The increase in position error of bodies A and B at Mach numbers greater than about 0.9 (figs. 7 and 8) is associated with the development of a supersonic region near the maximum thickness position of the body. The influence of the negative pressures on the body in this region cannot travel directly forward as at lower Mach numbers, but must travel around the supersonic region or through the subsonic boundary layer and is thus considerably attenuated at the position of the model static pressure orifices. The positive pressures near the nose of the body, however, are in a subsonic flow, and their effect is not attenuated. The net effect is an increase of the position error with Mach number to values that are large in comparison with the error at low Mach number. It should be noted, however, that, if the static orifices are located sufficiently far ahead of the nose of the body, the position error will be small at low Mach numbers and will remain of small absolute magnitude at all higher Mach numbers. For example, the position error at 1.7 diameters ahead of body B varied from 1.5 percent of q_c to a peak of 4 percent of q_c as the Mach number increased from 0.9 to 1.0.

As the free-stream Mach number becomes supersonic, a shock wave forms far ahead of the body and there terminates the pressure field.

With increasing supersonic speed, the pressure ahead of the body continues to increase, and the shock wave approaches the body. Finally, when the Mach number becomes sufficiently high, the shock wave passes over the orifices in the static pressure tube. At this point, a sharp decrease in the pressure at the orifices will occur (figs. 7 and 8) corresponding to the pressure change through a normal shock, except as modified by the curvature and thickness of the shock, and boundary-layer shock interaction. At this and higher Mach numbers, the static orifices will be completely isolated from the field of the body and will indicate the static pressure of the free stream, as seen in figures 7 and 8. For example, the Mach number at which the shock passed the orifices of body B varied from 1.0 at $\frac{x}{D} = 1.7$ to 1.05 at $\frac{x}{D} = 0.5$.

Comparison of pressure discontinuity with normal shock theory.-

The variation with Mach number of the pressure coefficient across a normal shock has been drawn in figures 7 and 8. For both bodies and at all positions of measurement, the discontinuity in pressure occurred approximately 0.02 Mach number lower than would be expected from the normal shock theory. Conversely, at a given Mach number, the pressure rise through shock was about 4 percent of q_c greater than that indicated by theory. More startling is the appearance of a shock involving a pressure rise of $0.04q_c$ at a Mach number of 1.0 (figs. 7(a) and 8(a)), where the theory indicates that no finite shock should exist. This basic disagreement between theory and experiment makes necessary a critical examination of the experimental technique as regards model interference, pressure lag, and instrumentation.

The possibility of model interference at the reference static tube was investigated by recomputing the data using the calibration with respect to the flush orifice. The data referred to the two calibrations agreed throughout the Mach number range. As would be expected, however, the data referred to the flush orifice calibration evidenced more scatter.

That model interference cannot account for the observed difference in the Mach number of shock passage can be seen from the following consideration. At the time when the shock reaches the model orifices, it must have already passed both reference orifices, inasmuch as the reference orifices are upstream of the model orifices. The reference orifices are then completely isolated from the field of the model and can in no way be influenced by it.

The model static orifices, after the shock from the body passed over them, furnish a point measurement of Mach number that is independent of the calibration. After passage of shock, the static pressure from the model orifices and the calibration agree within $0.01q_c$ (figs. 7 and 8), which corresponds to an agreement in Mach number within 0.005.

Thus, the Mach number immediately after shock passage is determined to within 0.005, whereas the disagreement between theory and experiment corresponds to a difference in Mach number as great as 0.02.

There seems to be no possibility of an appreciable pressure lag in the tubing. The lag of the reference static pressure tube used for obtaining the Mach number was computed and found to be negligible. During the tests of the bodies, the Mach number was varied so that the shock crossed the orifices in both the upstream and downstream directions, but no difference was noted in the magnitude of the pressure discontinuity or in the Mach number at which it occurred.

As a means of determining whether any unsuspected instrument errors were present, a check flight was made with body B with completely new instrumentation. No differences from previous measurements appeared, indicating the improbability of any consistent instrument errors. During this flight, a pull-up was made to a climbing attitude so that the static pressure at the model position decreased with time. The shock was found to recross the static orifices at the same Mach number as during the dives when the static pressure was increasing with time. This is additional evidence verifying the accuracy of the instrumentation and incidentally pointing to a negligible pressure lag. The effect of the position of the orifices behind the nose of the model static tube was determined by comparing the data obtained for body B with the short- and the long-nose static pressure tubes (figs. 8(a) and 8(c)). In figure 8(a), discontinuity in pressure associated with the passage of shock appeared less abrupt when the long-nose static pressure tube was used, possibly because of the thicker boundary layer. In figure 8(c), the peak position error was slightly lower with the long-nose tube. Neither the Mach number for shock passage nor the pressure rise through the shock, however, appeared appreciably affected by the change in nose length.

The experimental technique has been examined critically in the preceding paragraphs because of the observed disagreement of the data with the shock-wave theory. Inasmuch as no evidence was found to indicate an error of this magnitude in the experimental data, it would appear that this phenomenon warrants further investigation.

Variation of Position Error with x/D

Variation below body critical Mach number.— The variation of $\Delta p/q_c$ with x/D for Mach numbers less than 0.9 is shown for bodies A and B in figure 9(a). Data obtained at a low Mach number (reference 1) for a circular-arc body of fineness ratio 8.3 have been included. The variations of $\Delta p/q_c$ with x/D calculated by the linearized subsonic theory for the three bodies have been plotted in

figure 9(a) for comparison. The theoretical values of the position error are in good agreement with the values measured at Mach numbers less than 0.9. It is seen that the position error, large at short distances ahead of the nose, can be minimized through the use of a sufficiently long airspeed boom. In particular, the position error of body B was reduced from 8 percent of q_c at 0.5 diameter ahead of the nose to only 1.5 percent of q_c at a distance of 1.7 diameters.

Variation above body critical Mach number.- The maximum values of $\Delta p/q_c$ which occur just prior to the passage of shock across the static orifices are shown for bodies A and B as a function of x/D in figure 9(b). The peak position error of body B was reduced from 16.5 percent of q_c at 0.5 diameter ahead of the nose to 4.5 percent of q_c at a distance of 1.7 diameters. This error could be reduced further by going to larger values of x/D provided the airspeed boom does not become unwieldy.

Correlation for Bodies of Similar Shape

The data shown in figures 9(a) and 9(b) have been replotted in figures 10(a) and 10(c) as $(l/D)^2 \Delta p/q_c$ as a function of x/l . In the case of body B, which was unsymmetrical fore and aft, the length l was taken as twice that of the part of the body ahead of maximum thickness. This approximation is justified, since the forward part of the body is far more effective than the rear part in determining the magnitude of the position error.

Correlation below body critical Mach number.- The low-speed data ($M < 0.9$) from bodies A and B and from reference 1 all seem to correlate in figure 10(a) along a single curve. It may be shown by the linearized subsonic theory that, for bodies of revolution of the same family, that is, those having the same thickness distribution, the position error at a given fraction of the body length ahead of the nose is inversely proportional to the square of the fineness ratio. Since bodies A and B and that of reference 1 are all closely parabolic, the variation of $(l/D)^2 \Delta p/q_c$ with x/l calculated by the linearized subsonic theory for parabolic arc bodies is shown in figure 10(a) for comparison. The experimental data for Mach numbers less than 0.9 and for fineness ratios between 4.5 and 8.3 are seen to agree well with the theoretical curve which again shows the correctness and utility of the linearized theory.

Correlation above body critical Mach number.- The similarity law for axially symmetric transonic flow is discussed in reference 6, in which an expression is derived relating the pressure coefficients at

similar points on the contours and axes of bodies of revolution with the same thickness distribution. This expression with changed notation is

$$\frac{\Delta p}{q} = \left(\frac{D}{l}\right)^2 F \left[\frac{\left(\frac{D}{l}\right)^2 \frac{\gamma + 1}{2}}{M - 1}, \frac{x}{l} \right] \quad (1)$$

For all cases in which the fluid is the same, the term $\frac{\gamma + 1}{2}$ may be omitted. The first parameter becomes infinite at $M = 1$ so that it will be more convenient to use its reciprocal. If, then, equation (1) is rearranged, we have

$$\left(\frac{l}{D}\right)^2 \frac{\Delta p}{q} = F \left[\left(\frac{l}{D}\right)^2 (M - 1), \frac{x}{l} \right] \quad (2)$$

Equation (2) shows that all bodies with a given thickness distribution will, at equal values of x/l , exhibit the same variation of $\left(\frac{l}{D}\right)^2 \frac{\Delta p}{q}$ with $\left(\frac{l}{D}\right)^2 (M - 1)$.

From cross plots of figures 7 and 8 at Mach numbers above 0.9, the data of bodies A and B have been replotted in figure 10(b) as $\left(\frac{l}{D}\right)^2 \frac{\Delta p}{q_c}$ as a function of $\left(\frac{l}{D}\right)^2 (M - 1)$ for several constant values of $\frac{x}{l}$ and are seen to correlate in the manner predicted in equation (2). It is indicated again in figure 10(b) that the bow shock waves pass the static orifices at Mach numbers less than those predicted by normal-shock theory.

Correlation of peak position error.— The peak values of the position error for bodies A and B shown in figure 9(b) have been replotted in figure 10(c) as $\left(\frac{l}{D}\right)^2 \frac{\Delta p}{q_c}$ as a function of $\frac{x}{l}$ and appear to correlate on a single curve in the same manner as below the body critical Mach number. It will be shown that, for the particular case of peak position error, the transonic similarity law suggests exactly this correlation.

Equation (2) can be simplified for the case of the peak position error on the axis of the body. The peak value of $\frac{\Delta p}{q}$ is connected with M by the normal shock relations, inasmuch as the peak value occurs just behind a normal shock. For slightly supersonic Mach numbers, $\frac{\Delta p}{q}$ across a normal shock varies approximately linearly with $M - 1$ (linear for observed as well as theoretical), so that $M - 1$ may be replaced by $K\frac{\Delta p}{q}$, where K is a constant. Equation (2) then becomes

$$\left(\frac{l}{D}\right)^2 \frac{\Delta p}{q} = F \left[K \left(\frac{l}{D}\right)^2 \frac{\Delta p}{q}, \frac{x}{l} \right]$$

or

$$G \left[\left(\frac{l}{D}\right)^2 \frac{\Delta p}{q}, \frac{x}{l} \right] = 0 \quad (3)$$

Equation (3) defines a single curve in the ordinates of figure 10(c) and therefore corroborates the observed correlation of the peak position errors for bodies A and B.

Application of correlation.— For bodies with fineness ratio different from those tested, an estimate of the low-speed and peak position errors can be made from figures 10(a) and 10(c) provided the profile of the body nose is a reasonable approximation to a parabolic arc. For example, it is required to find the length of airspeed boom for use on a fineness ratio 12 parabolic body to give a peak position error of 2 percent of q_c . From the peak position error curve in

figure 10(c) for $\left(\frac{l}{D}\right)^2 \frac{\Delta p}{q_c} = 2.88$ is found $\frac{x}{l} = 0.135$, which is equivalent to a length of 1.62 maximum body diameters. From figure 10(a)

for $\frac{x}{l} = 0.135$, the corresponding low-speed position error is found to be $0.008q_c$. The transition of the position error from the low-speed value to the peak value can be determined as a function of Mach number from

figure 10(b) for $\frac{x}{l} = 0.135$. With this final step, the complete position-error curve for all Mach numbers is determined, inasmuch as the position error at Mach numbers above that for shock passage is zero. These results should be valid for fineness ratios $\frac{l}{D}$ at least as low as 4.5 and distances ahead of the nose $\frac{x}{l}$ as small as 0.1. The upper limits of these values of $\frac{l}{D}$ and $\frac{x}{l}$ are presumed to be unrestricted.

CONCLUSIONS

Measurements made by the wing-flow method at Mach numbers up to 1.1 of the static-pressure (or position) error ahead of two sharp-nose bodies of revolution at zero angle of attack have indicated that:

1. By application of the linearized subsonic theory and the transonic similarity rule to the data contained herein, the position error at any reasonable distance ahead of any sharp-nose body of revolution with an approximately parabolic nose profile and fineness ratio greater than about 4.5 can be predicted at any Mach number.

2. The position error will be of small magnitude at all Mach numbers if the static pressure orifices are located sufficiently far ahead of the nose of the body. For example, at 1.5 diameters ahead of the bodies tested, the position error was about 1.5 percent of q_c (free-stream impact pressure) up to a Mach number of 0.9, increased thereafter to 4 percent of q_c at a Mach number of 1.0, then immediately disappeared as the shock from the body passed over the static orifices and remained zero at higher Mach numbers.

3. The low-speed and peak position errors both increase as the orifices are moved toward the body nose. For example, the low-speed position error of the body that corresponded roughly to the X-1 airplane fuselage varied from about 1.5 to 8.0 percent of q_c as the static pressure orifices were moved from 1.7 to 0.5 maximum body diameters ahead of the nose of the body. The corresponding variation in the peak position error of this body was from 4.5 to 16.5 percent of q_c .

4. In the range of applicability of the linearized subsonic theory, that is, at Mach numbers below that for the first appearance of sonic speed on the body, the prediction of the linearized theory that the position error is independent of Mach number was experimentally verified. The magnitude of the position error in this Mach number range was also adequately predicted by the theory..

5. For bodies of a given thickness distribution in the range of Mach number for which the position error is constant, the position error

at a given fraction of the body length ahead of the nose was found experimentally to be inversely proportional to the square of the fineness ratio. This result may also be shown to follow as a consequence of the linearized subsonic theory.

6. The transonic similarity rule for axially symmetric flow was found to furnish a good correlation of the position errors of the two bodies at all Mach numbers greater than about 0.9.

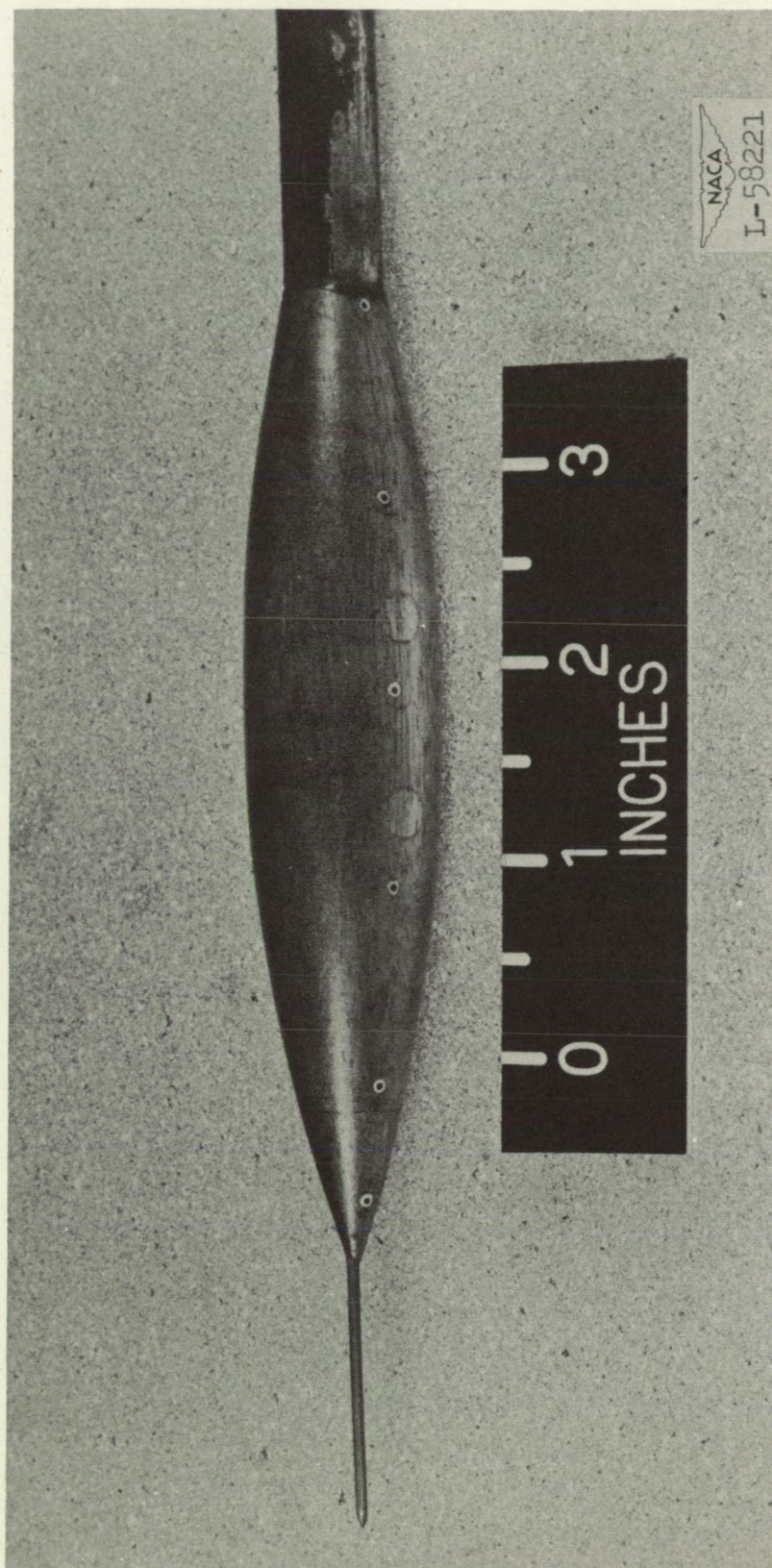
7. The pressure rise through the bow shock wave was found in all cases to be about 4 percent of q_c greater than that indicated by the normal shock theory. More startling was the appearance of a shock involving a pressure rise of $0.04q_c$ at a Mach number of 1.0 where the theory indicates no finite shock should exist. Inasmuch as no evidence was found to indicate an error of this magnitude in the experimental data, it would appear that this phenomenon warrants further investigation.

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REFERENCES

1. Hensley, Reece V.: Calibrations of Pitot-Static Tubes at High Speeds. NACA ACR, July 1942.
2. Hasel, Lowell E., and Coletti, Donald E.: Investigation of Two Pitot-Static Tubes at Supersonic Speeds. NACA RM No. L8I02, 1948.
3. Letko, William: Investigation of the Fuselage Interference on a Pitot-Static Tube Extending Forward from the Nose of the Fuselage. NACA TN No. 1496, 1947.
4. Göthert, B.: Plane and Three-Dimensional Flow at High Subsonic Speeds. NACA TM 1105, 1946.
5. Danforth, Edward C. B., and Johnston, J. Ford: Pressure Distribution over a Sharp-Nose Body of Revolution at Transonic Speeds by the NACA Wing-Flow Method. NACA RM No. L7K12, 1948.
6. Von Kármán, Theodore: The Similarity Law of Transonic Flow. Jour. Math. and Phys., vol. XXVI, no. 3, Oct. 1947, pp 182-190.

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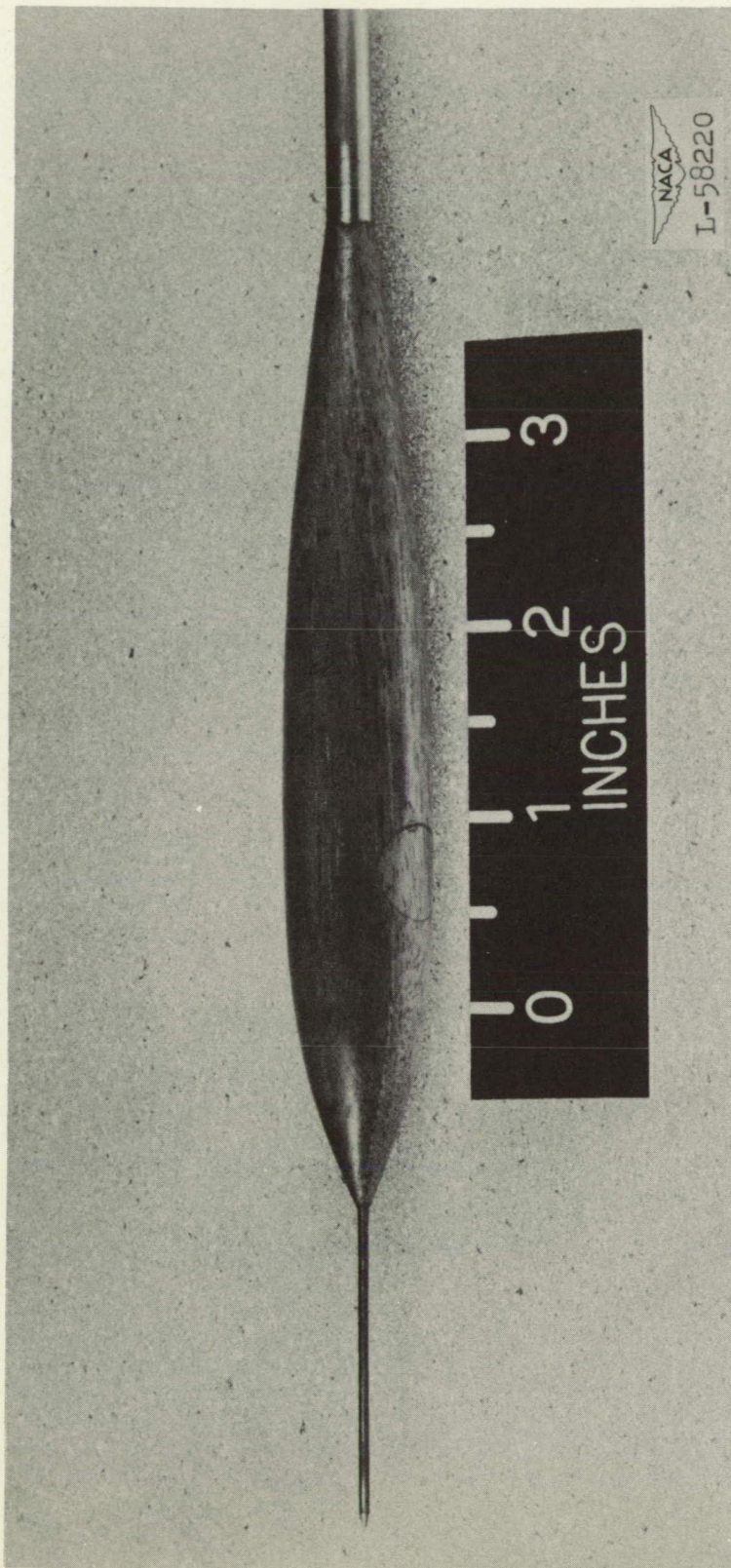


(a) Body A.

Figure 1.- Photographs of models.

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(b) Body B.

Figure 1.- Concluded.
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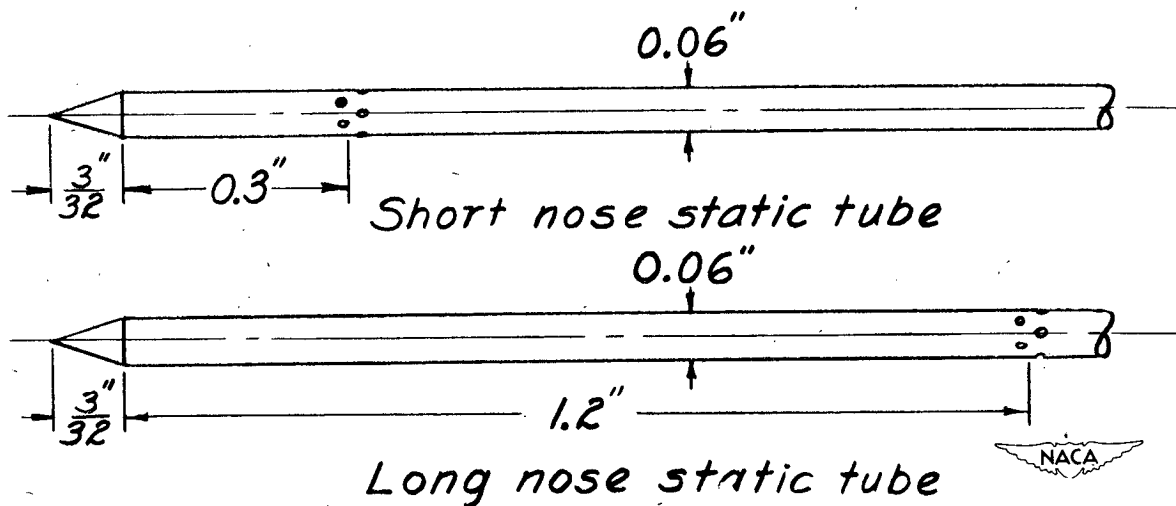
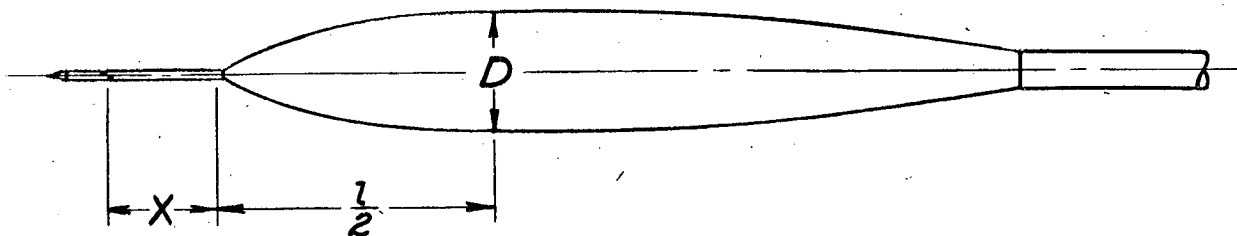
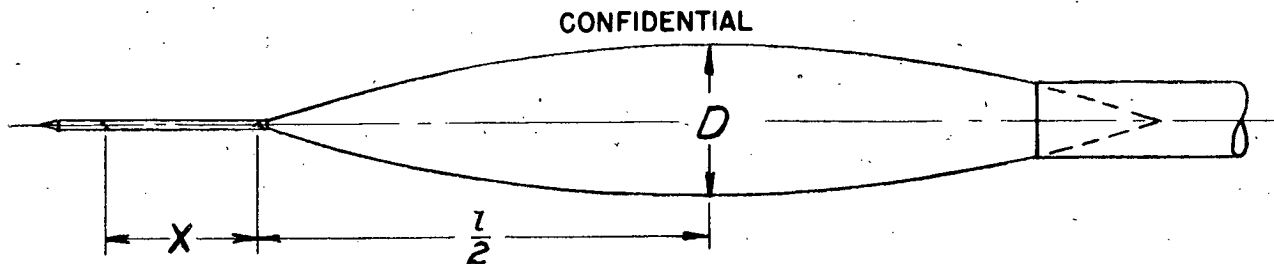


Figure 2.- Sketch of bodies and model static pressure tubes.

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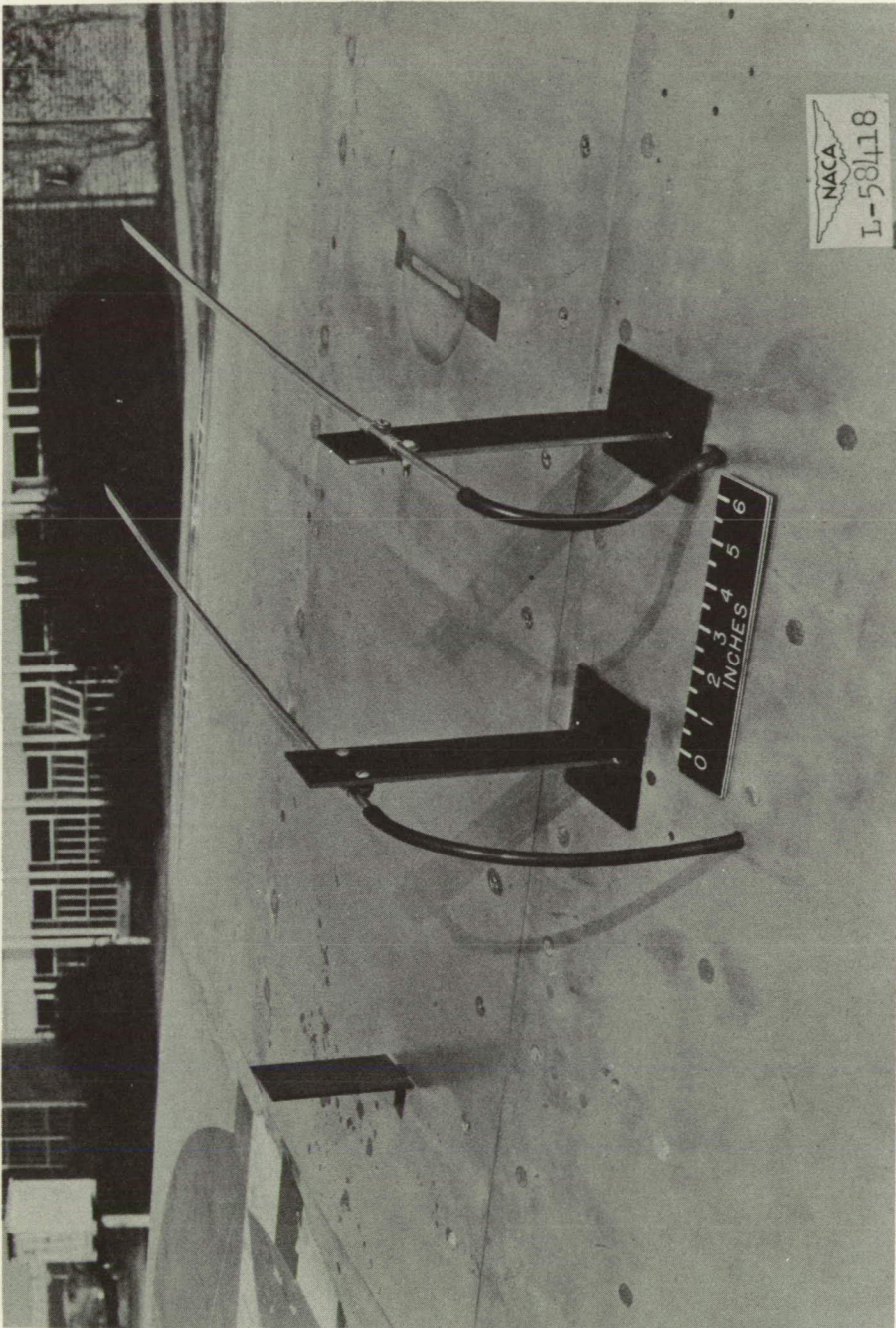


Figure 3.- Static pressure tubes used in calibration.

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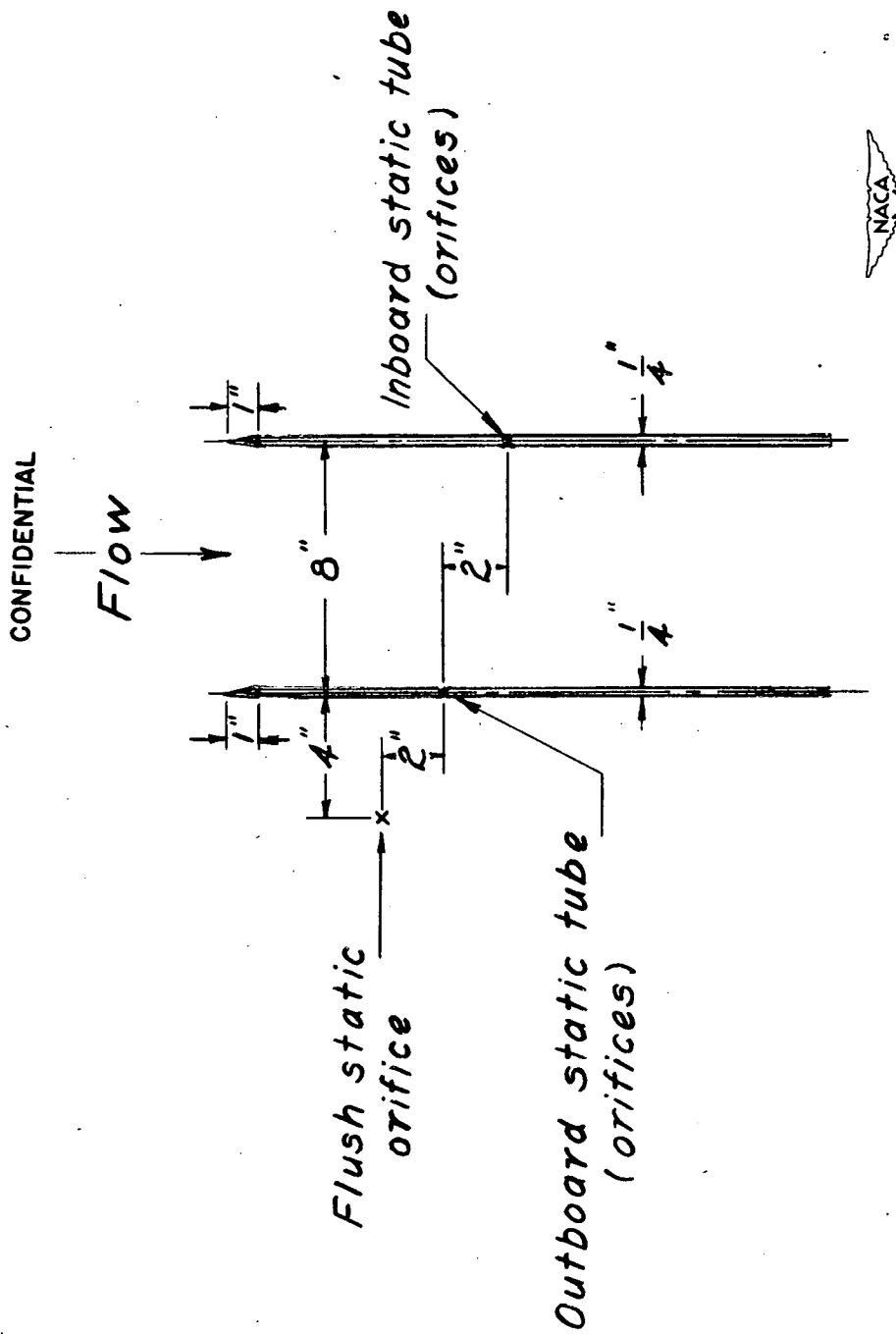
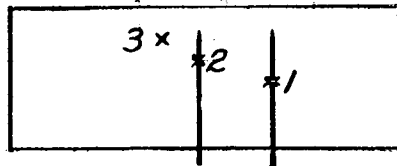


Figure 4.- Location of orifices used to calibrate the test panel.

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Flow ↓



Test panel and measuring points

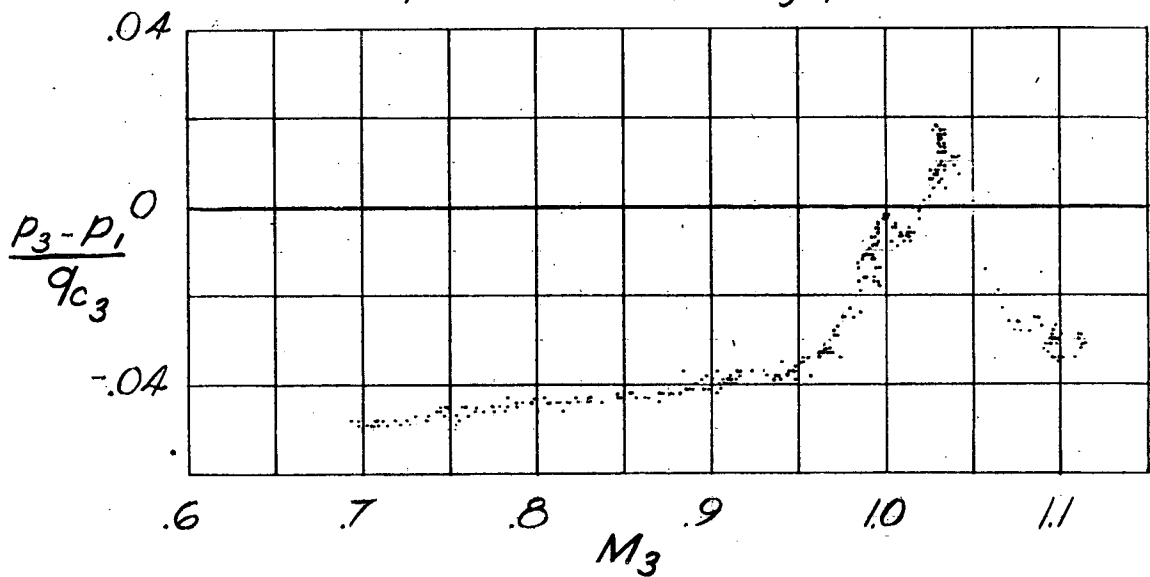
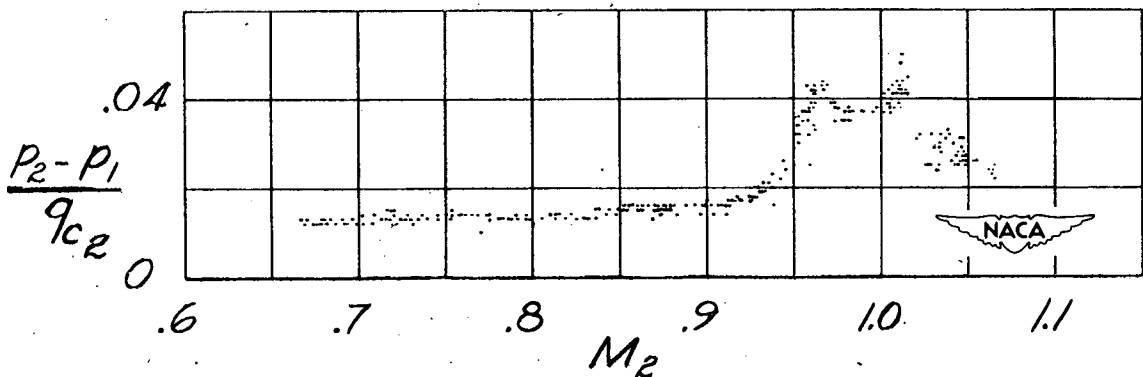
(a) Variation of $\frac{P_3 - P_1}{q_{c3}}$ with M_3 .(b) Variation of $\frac{P_2 - P_1}{q_{c2}}$ with M_2 .

Figure 5.- Calibration of test panel.

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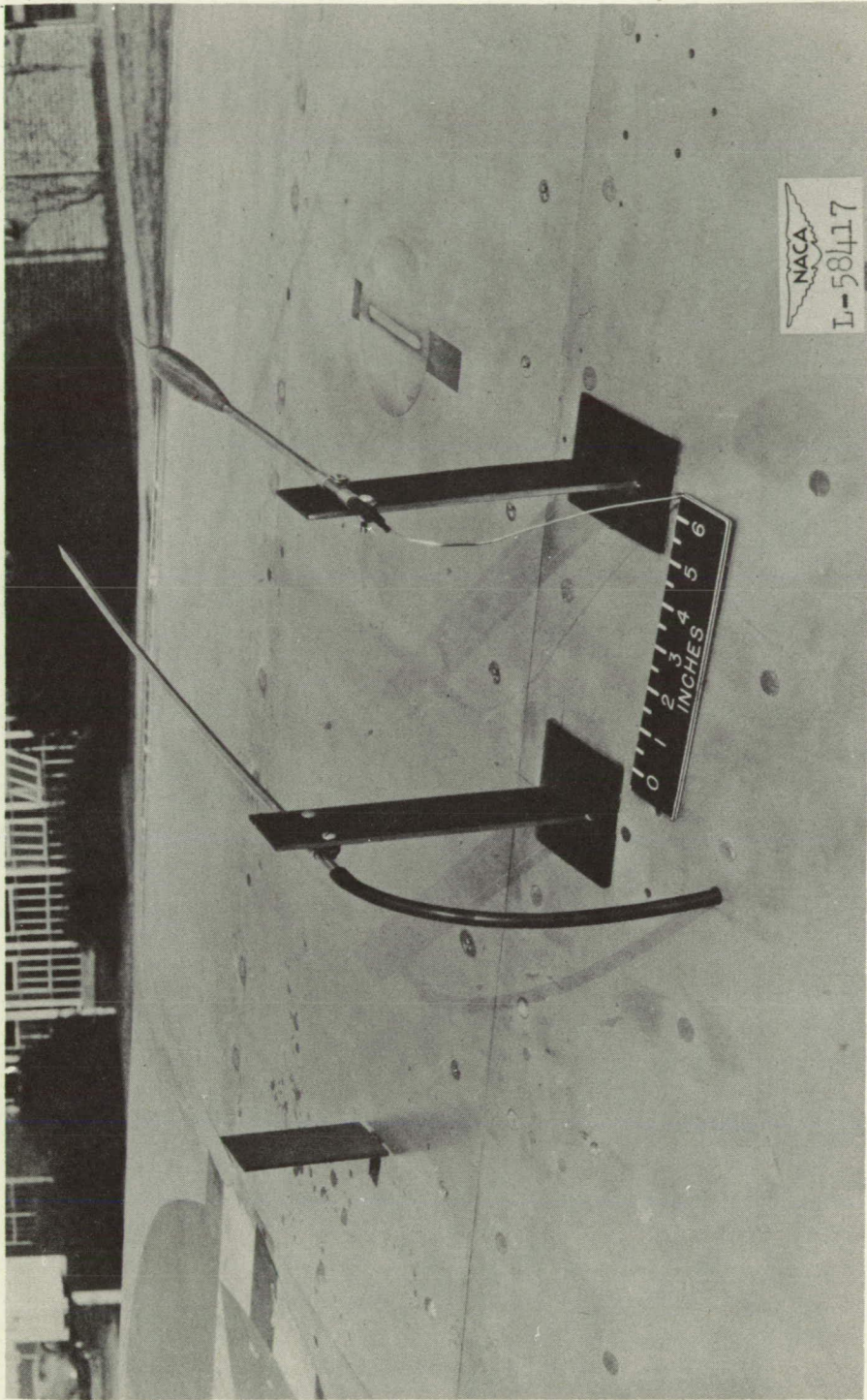
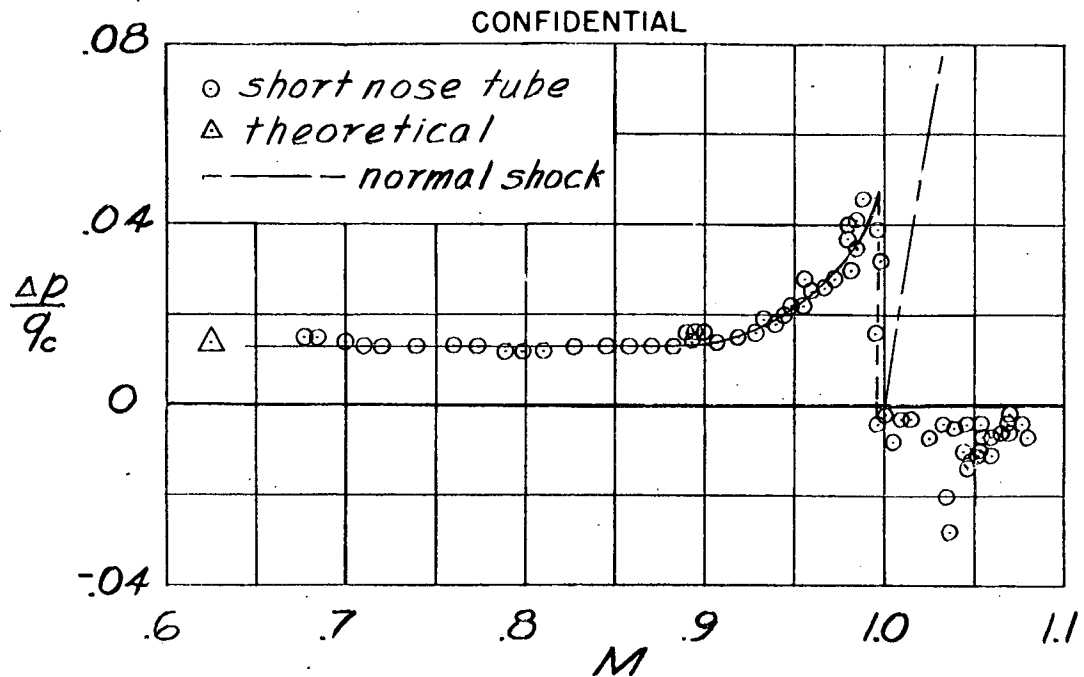
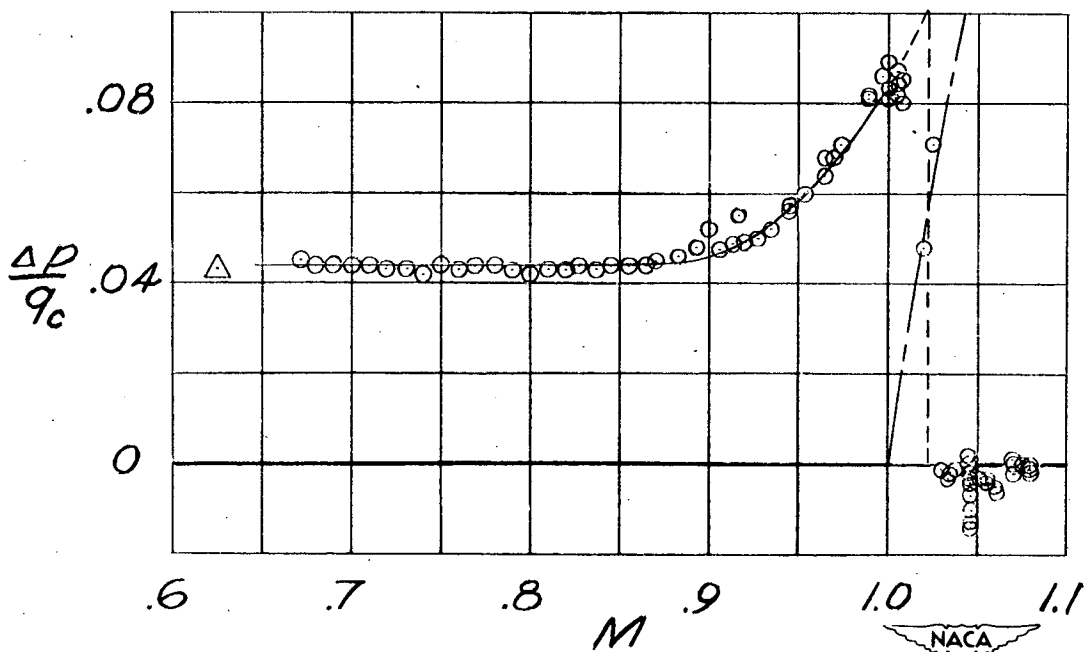


Figure 6.- Body B and reference static pressure tube mounted on test panel.

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(a) $\frac{X}{D} = 1.5$.



(b) $\frac{X}{D} = 0.6$.

Figure 7.- Position error ahead of body A.

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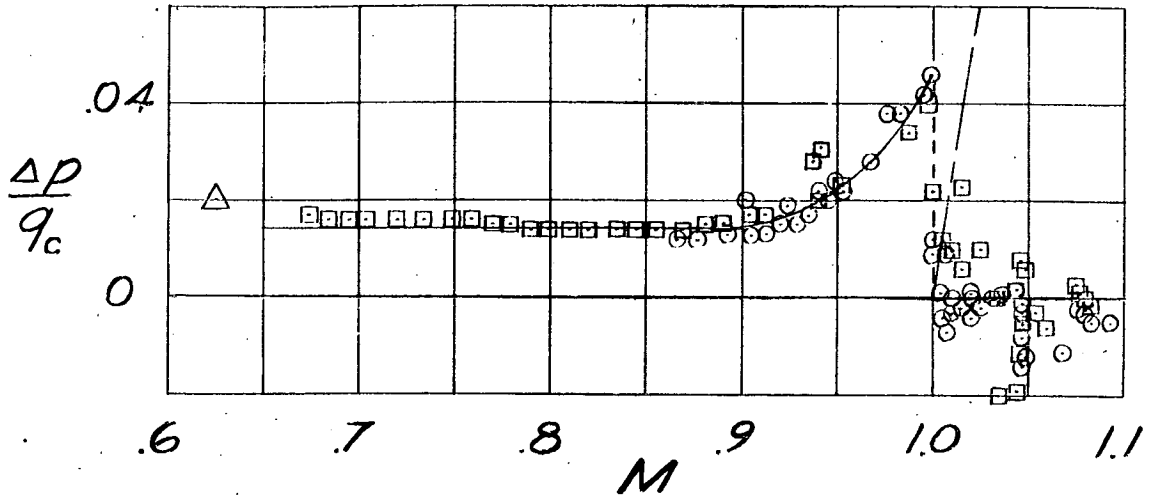
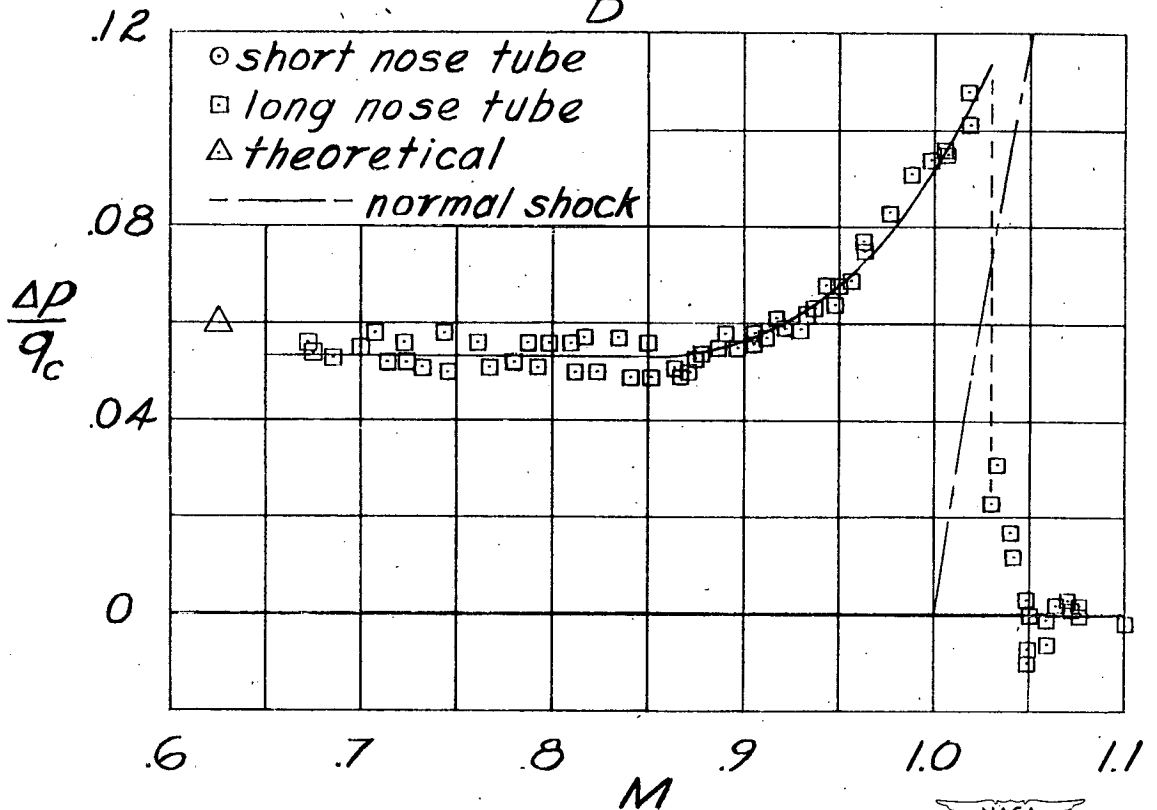
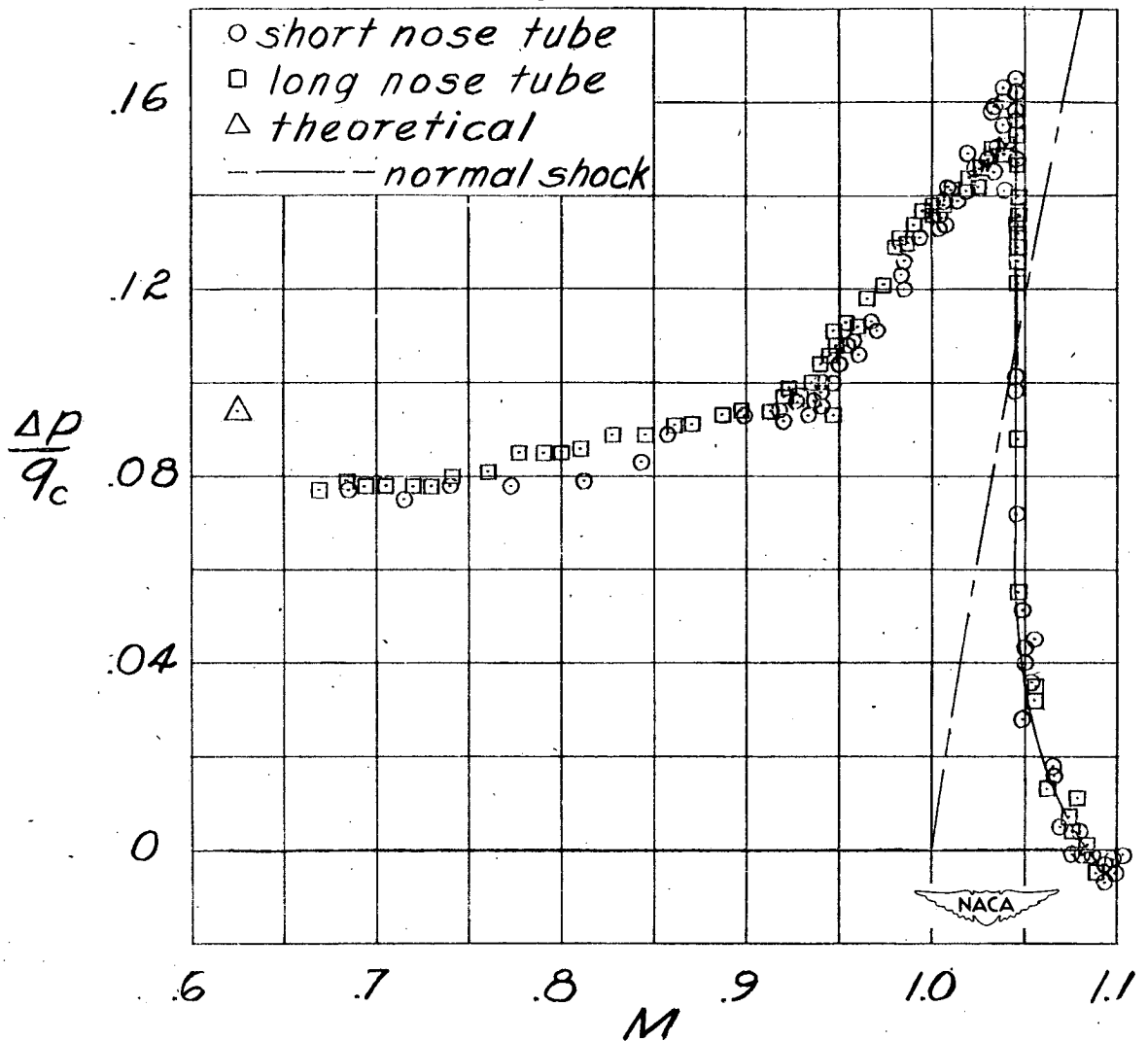
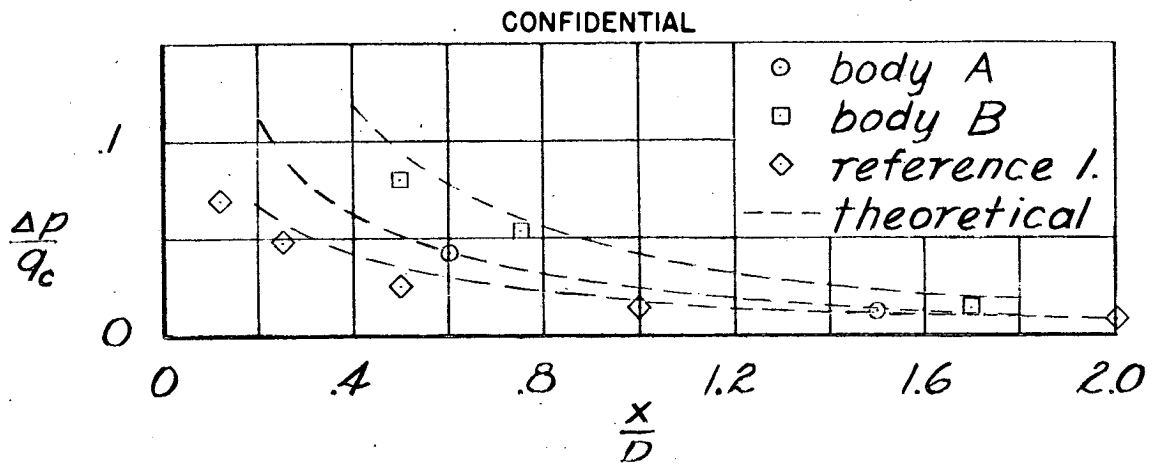
(a) $\frac{X}{D} = 1.7.$ (b) $\frac{X}{D} = 0.75.$ 

Figure 8.— Position error ahead of body B.

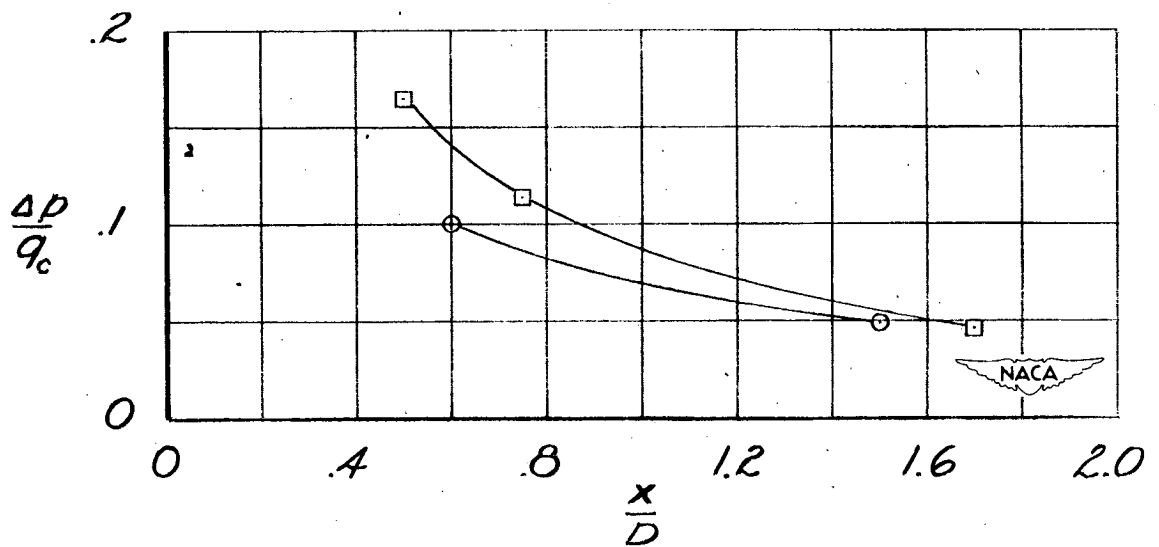
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(c) $\frac{x}{D} = 0.5$.Figure 8.- Concluded.
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(a) Below body critical Mach number.



(b) Peak position error.

Figure 9.— Variation of position error with distance ahead of body nose.

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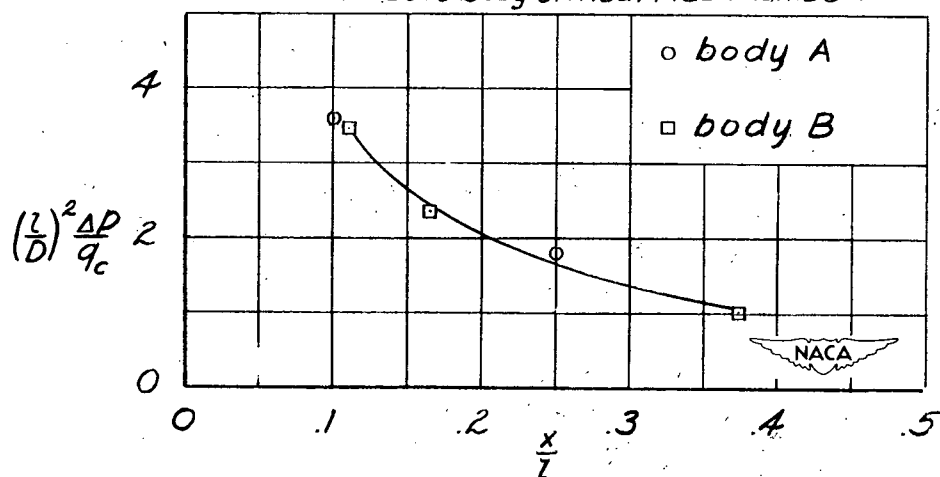
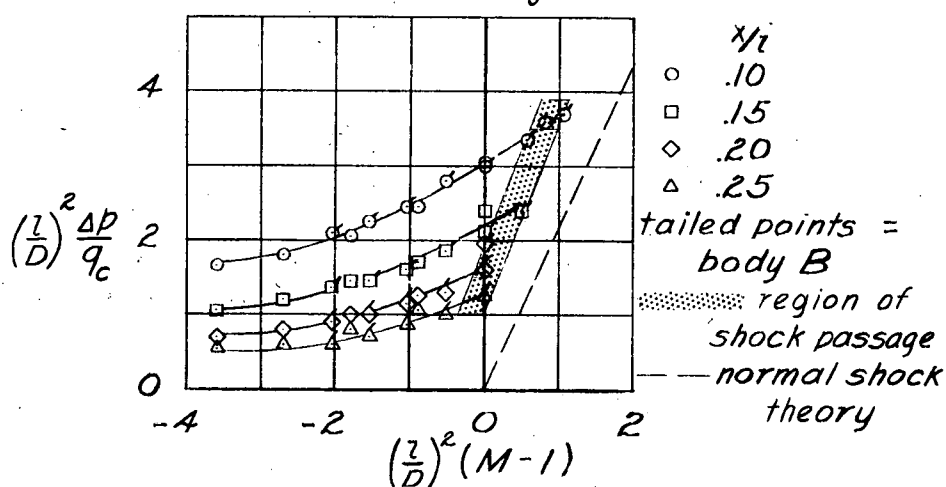
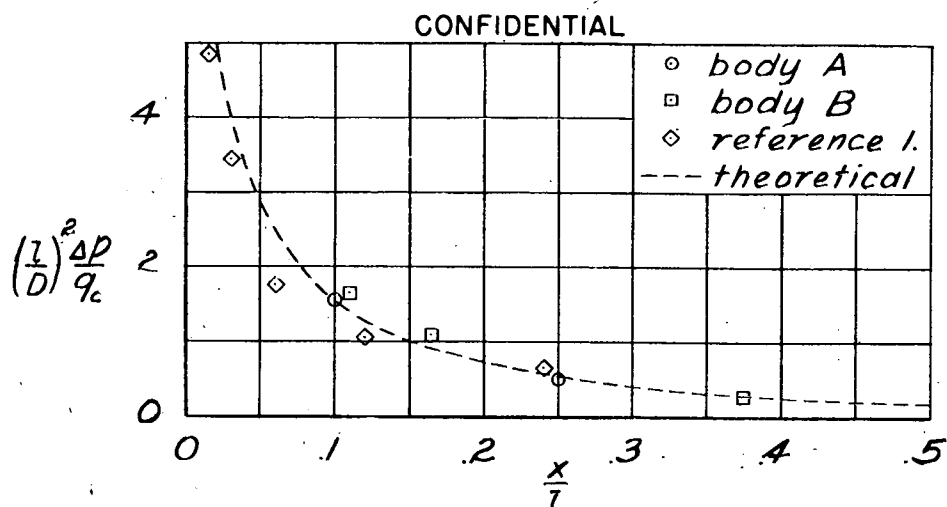


Figure 10.— Correlation for bodies of a given thickness distribution.

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